ST[EMpower]

PALEONTOLOGY - Intro

VOLUME 9, ISSUE 1, SEPTEMBER 2019

THIS MONTH

POWER WORDS

- **biomechanics**: the mechanics of biological and especially muscular activity, as in locomotion
- **e.g.**: exempli gratia, for example
- epidemiology: branch of medicine which deals with the incidence, distribution, and possible control of diseases
- **multidiscipline**: combining or involving more than one field of study
- **taphonomy**: the study of the processes (such as burial, decay, and preservation) that affect animal and plant remains as they become fossilized

CAREERS

- How to begin exploring careers? Interest survey on page 31.

INTRODUCTION TO PALEONTOLOGY

Paleontology is the study of past life. Our focus is on how life arose on our planet, starting with the earliest fossils found - bacteria. Through time, we find episodes of mass extinctions, followed by a new groups of organisms arising.

Paleontology is a **multidiscipline** science. Most paleontologists use both geology and biology in our work. Some other fields of study include physics (**e.g. biomechanics**), chemistry (**e.g. taphonomy**), or even human medicine's study of disease epidemics (**e.g. epidemiology**). Dr. Bruce Rothschild, a medical doctor, has identified a mastodon (an extinct elephant) had tuberculosis, a barosaur (a long-necked sauropod) had arthritis, and the *T. rex,* Sue, had gout. Cool!

What do paleontologists do? Most people think that they spend their time in the badlands digging up dinosaur fossils. Not all paleontologists work in the fields. It is only one part of what a paleontologist does in their career. These scientists are primarily professors at universities or curators and fossil preparators at museums.

Get ready for a year of exploring the amazing life of the past on planet Earth. Yes, there will be an entire issue on the science of dinosaurs, but also the wonderful and weird life that has existed on our planet for billions of years!

The most beautiful thing we can experience is the mysterious.
Albert Einstein

Panochthus tuberculatus, Museo de La Plata, Argentina

Humans can "feel" about 100 years. That is close to a human life, so we have a grasp of that. You may have a grandparent or great-grandparent in his or her 80s, 90s, or even 100.

What about 500 years? In 1519:

- Christopher Columbus had discovered the New World only 27 years earlier.
- Hernan Cortés invaded Mexico and conquered the Aztec Empire.
- Ferdinand Magellan sets sail on his voyage around the world.
- Cacao beans arrive in Europe (chocolate is made from cacao beans).

What about 1,000 years? In 1019:

- The age of the Vikings is drawing to a close.
- The Holy Sepulcher in Jerusalem destroyed, the event that lead to the start of the Crusades at the end of this century.

That is just a measly 1,000 years ago. The best estimate of the age of our universe is 14 billion years old. Our solar system and the Earth are estimated to have formed around 4.6 billion years ago. Multicellular life with hard parts appear suddenly in the fossil record about 550 million years ago.

Human can calculate big numbers. We can use scientific notation to make big numbers easier to manipulate. We can talk about exponential increases or decreases. We can talk about billionaires, our national debt in the trillions. We, however, cannot fathom big numbers.

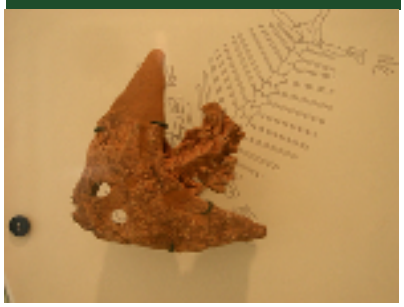
This activity is to give you a better feel for big numbers as well as amaze and astound you! Not only that, you get to play with math! Wahoo!

Directions:

- Go to the first website listed in the green box. You need a flash player, but then can spend time zooming scale from minute to immense. Way too cool!
- The next website is a short film about exponential numbers traveling from the quarks in the nucleus of an atom to the farthest reaches of our universe.
- Some websites included scientific notation. Enormous numbers are much easier to use in calculations. For example, 1,500,000,000,000 meters can be written 1.5×10^{12} m (m is the abbreviation for meter). There are 12 digits following the 1. The decimal is moved 12 spaces to the right. If the digit following the decimal is not written, it is a zero. Another way to write 1 trillion, 5 hundred billion is 15×10^{11}.
- How would you write 76,250,000 as a scientific notation?
- What is this number: 62.5×10^{21}
- What is this number: 7×10^{3}
- Answers are on page 34 (the last page).
- Get ready to be amazed!

POWER WORDS

- **digit**: any of the numerals from 0 to 9 when forming part of a number
- **exponential**: increase or decrease quickly by large amounts
- **quark**: a subatomic particle carrying a fractional electrical charge
- **scientific notation**: a way of writing very large or very small numbers



Amphibian *Diplocaulus* from the Carboniferous - Permian (315-290 million years ago)

MATERIALS:

- computer with internet connection
  https://scaleofuniverse.com/
  https://www.youtube.com/watch?v=jfSNxVqprvM
  pencil
- calculator or cell phone
- print pages 7-11
- scissors or box cutter
- packing tape
- recycled cardboard boxes (bigger is better)
- tape measure

Directions:

There are 52 weeks between today and this date next year. What would your allowance be if you receive 1 cent the first week, and it is doubled each week? What is your allowance at the end of the year?

Week #	Doubled (x 2)	Allowance Total
1.		$0.01
2.	0.01 x 2 = 0.02	$0.03
3.	0.02 x 2 = 0.04	$0.07
4.	0.04 x 2 = 0.08	$0.15
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		
16.		
17.		
18.		
19.		
20.		
21.		
22.		
23.		
24.		
25.		

BIG NUMBERS - Allowance continued

Week #	Doubled	Allowance
26.		
27.		
28.		
29.		
30.		
31.		
32.		
33.		
34.		
35.		
36.		
37.		
38.		
39.		
40.		
41.		
42.		
43.		
44.		
45.		
46.		
47.		
48.		
49.		
50.		
51.		
52.		

How long do you think one million (1×10^6) seconds is? Make a guess in years, months, days, etc.:

one million = 1,000,000 = (1×10^6)

There are a couple ways to approach this problem. One way is to use division.

Start by dividing 1,000,000 by 60 seconds to get the number of minutes in 1 million

1,000,000 / 60 (on a calculator, enter 1,000,000 ÷ 60 = M minutes)

Next, find the number of hours by dividing your answer by 60 minutes

M / 60 (on a calculator, enter the answer to minutes M ÷ 60 = H hours)

Find the number of days by dividing by your last calculation by 24 hours

H / 24 (on a calculator, enter the answer to hours H ÷ 24 = D days)

Find the number of weeks by dividing your last calculation by 7

D / 7 (on a calculator, enter the answer to days D ÷ 7 = W weeks)

Find the number of months by dividing your last calculation by 4.33
(average of 4.33 weeks in 1/12 of the year—assuming that each month is 30.4375 days)

W / 4.33 (on a calculator, enter the answer to weeks W ÷ 4.33 = Mo months)

Finally, find the number of years by dividing your last calculation by 12

Mo / 12 (on a calculator, enter the answer to weeks W ÷ 12 = Y years)

Are you surprised how long one millions seconds is? Did you think it shorter or longer than your calculation?
(record your response below.)

How long do you think one billion seconds is? Make a guess in years, months, days, etc.:

one billion = 1,000,000,000 = (1×10^9)

Start by dividing 1,000,000 by 60 seconds to get the number of minutes in 1 million

1,000,000 / 60 (on a calculator, enter 1,000,000 ÷ 60 = M minutes)

Next, find the number of hours by dividing your answer by 60 minutes

M / 60 (on a calculator, enter the answer to minutes M ÷ 60 = H hours)

Find the number of days by dividing by your last calculation by 24 hours

H / 24 (on a calculator, enter the answer to hours H ÷ 24 = D days)

Find the number of weeks by dividing your last calculation by 7

D / 7 (on a calculator, enter the answer to days D ÷ 7 = W weeks)

Find the number of months by dividing your last calculation by 4.33
(average of 4.33 weeks in 1/12 of the year—assuming that each month is 30.4375 days)

W / 4.33 (on a calculator, enter the answer to weeks W ÷ 4.33 = Mo months)

Finally, find the number of years by dividing your last calculation by 12

Mo / 12 (on a calculator, enter the answer to weeks W ÷ 12 = Y years)

Are you surprised how long one billion seconds is? Did you think it shorter or longer than your calculation?
(record your response below.)

To find out how old you will be in 1 trillion seconds, add three zeros to your answer for 1 billion seconds.

To find out how old you will be in 1 quadrillion seconds, add three more zeros.

Look carefully at these numbers and write what you observe about them:

One	1
One thousand	1,**000**
One million	1,000,**000**
One billion	1,000,000,**000**
One trillion	1,000,000,000,**000**
One quadrillion	1,000,000,000,000,**000**
One quintillion	1,000,000,000,000,000,**000**

Can you calculate your age in Months? Days? Weeks? Hours? Minutes? Seconds?

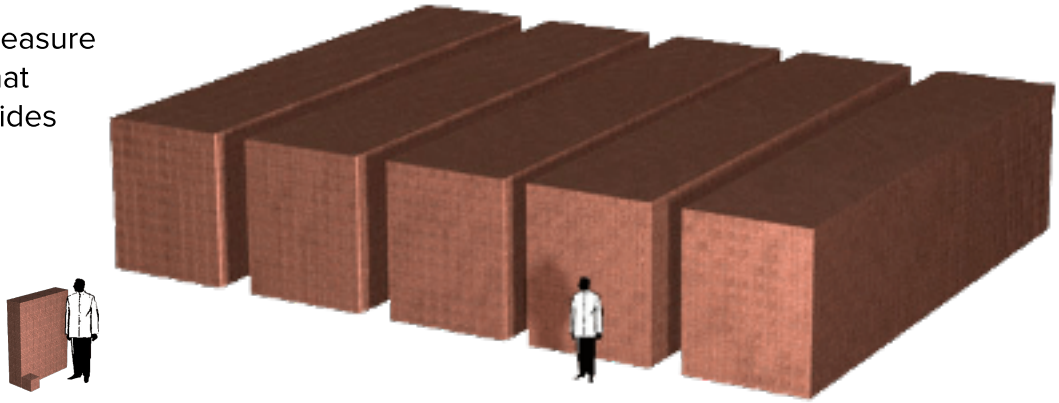
The last project on big numbers is the size of 1 million pennies stacked. For this one, you need the cardboard boxes, a box cutter or good pair of scissors, packing tape, measuring tape, and parent supervision.

The images below represent the stack of:

- 1 million pennies (a wall 5 feet high, 4 feet long, 1 foot wide, plus the cube of 1 foot cubed)
- 1 billion pennies (the size of 5 large school buses or 5 cargo train boxes)

Directions:

- You need cardboard in the following sizes (note - sizes are in feet):
  - two at 5' x 4' (front and back)
  - one 4' x 3' (or six at 1' x 1') for the 1' cube
  - two at 5' x 1' (sides)
  - two at 4' x 1' (top and bottom)
- Cut the sides of the box to make one large flat cardboard sheet. Lay it on the ground. If you have large boxes, you may have sides that are 5 x 4 feet. If not, cut and tape the cardboard to be that size using the packing tape to hold them together.
- Once you have all your pieces cut out, tape the two 5' x 1' sides to the front. Tape the 4' x 1' top to the top of the front, and the 4' x 1' bottom to the bottom of the front cardboard.
- Tape the edges of the top to the sides and the bottom to the sides. You will now have an open box.
- Tape the back to the opening on your open box.
- Use page 5 as the template. Measure and draw six 1' x 1' squares in that pattern. Cut out and tape the sides together for the 1' x 1' cube.
- Viola! You have the size of 1 million pennies in cardboard!



The foundation of paleontology is built on both geology and biology.

The Earth is made from layers.

Directions - Detanglers:

- Print pages 10-11. Try not to read the cards. Cut the clue cards apart on page 10. Cut the distances apart on page 11.
- You need 6 people total, so get 5 family or friends together.
- Place the 6 clue cards face down, mix them up, and each person picks one.
- *Read these directions:*
  - Pick one Detangler clue card. Do not show your card to anyone else in your group.
  - Read your clues. Do not show your card to anyone.
  - Your group task is to label the diagram of the Earth's interior, include the name and size of each area, and calculate the distance to the center.

Plate **tectonics** is the scientific theory of describing the motion of the seven large and many smaller plates of the Earth's **lithosphere**. The plates move in relationship to other plates in one of three ways:

1. **Convergent boundary**: One plate slides under another plate by **subduction**. As the heavier plate is forced deeper under the lighter plate, it heats and melts the rock. **Magma** (Power Word on page 9) forms volcanoes. The Cascade Range on the Pacific Coast is formed through this action. The leading edge of the **subducted** plate is destroyed.
2. **Divergent boundary**: Two plates separate. As they move further from each other, magma wells up into that gap. The East African Rift is formed through this action. The gap is constructive in that it forms new rock.
3. **Transform boundary**: Two plates grind next to each other. The plates may snag and hold, but when they release, it causes earthquakes. San Andreas Fault in California is an example.

Directions - Model Plate Tectonics:

- The inner core of the Earth is extremely hot, solid nickel and iron (grape). The outer core is a melted liquid nickel and iron (honey). The mantel is composed of silicate rock and is an extremely viscous solid/liquid (orange). It is the interface (frosting) between the mantle and crust (surface of the Earth; orange rind) that allow the tectonic plates to slowly move.
- Peel the orange with large pieces of rind (tectonic plates on the surface of the Earth).
- Keep the orange as one piece (mantle). Add some frosting at the bottom of the orange sections to seal the center.
- Push the grape (solid inner core) into the center of the orange.
- Carefully add about 1 teaspoon honey (liquid outer core) into the

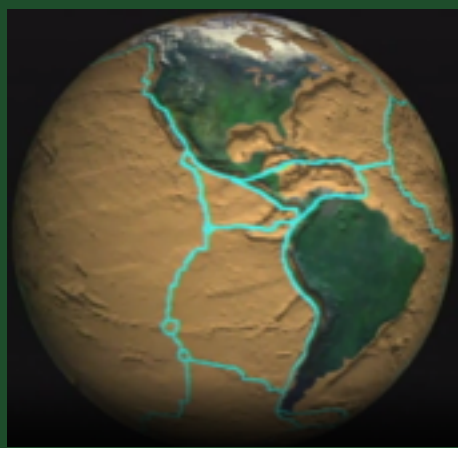
POWER WORDS

- **convergent boundary:** destructive - two plus **tectonic** plates collide; one plate eventually slides beneath the other causing a process known as subduction
- **divergent boundary**: - constructive - linear feature that exists between two **tectonic** plates that are moving away from each other
- **lithosphere**: the rigid outer part of the Earth, consisting of the crust and upper mantle
- **subduction**: sideways and downward movement of the edge of a plate of the Earth's crust into the mantle beneath another plate
- **tectonic**: large-scale processes affecting the structure of the Earth's crust
- **transform boundary**: two **tectonic** plates slide past one another
- **viscous**: thick consistency between a liquid and solid

MATERIALS:

- 5 family members and friends plus you
- print pages 10-11
- scissors
- orange
- frosting (any flavor)
- honey
- grape
- paper towels
- plate
- computer with Internet

Major plate boundaries of the New World



center of the of the orange around the grape.

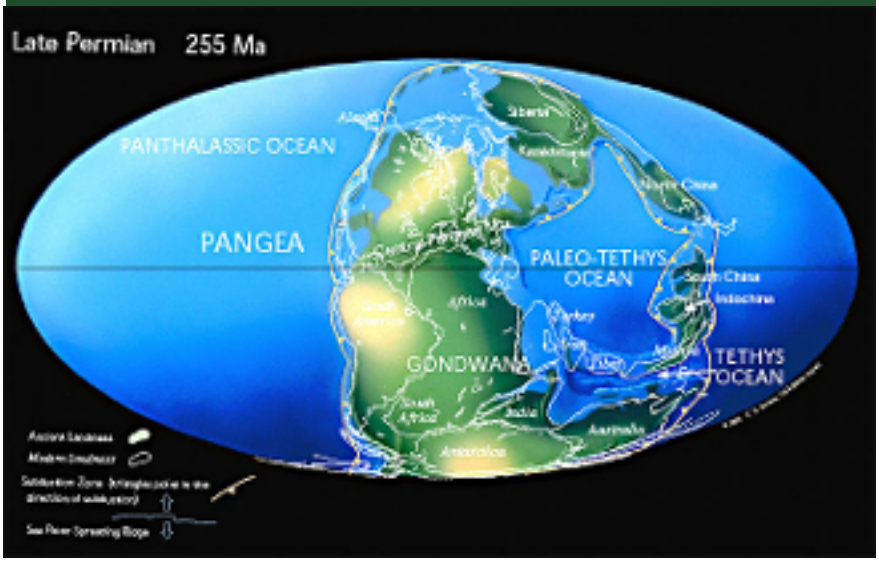
- Frost the entire orange with frosting (**lithosphere** - the interface between the mantle and crust). You will need a fairly thick layer (1/2 centimeter) to demonstrate plate tectonics.
- Place the orange rind on the orange, and the frosting holds everything in place. The orange zest (orange color at the top of the rind) represents the crust.
- Place the model of the Earth on the plate.
- To model **divergent plates**, gently press down and apart on two adjacent rinds. You want to have the frosting bulge out as the two rinds move away from each other. You may need to try several times to demonstrate how the magma wells up into the opening. This represents magma oozing up through the gap, forming new rock.
- To model **convergent plates**, push two rinds together, forcing one under the other. As one plate is forced deeper into the Earth, the rock eventually melts. When the **magma** builds enough pressure, it is forced out through volcanoes or fissures as **lava**.
- To model **transform boundaries**, press two rinds together, grinding one by the other. This type of movement causes earthquakes.
- Enjoy your orange!
- You may know about the modern technology of interactive maps. You can learn ArcGIS map making, a way to layer maps with information. Unfortunately for paleontologists, they are not deep-time sensitive. Instead, we use maps developed by a skilled paleo-geologist, Dr. Christopher Scotese. He has spent decades researching Earth's history and developing maps of how continents moved through time. His website is Paleo Map Project listed below. The left bar menu has several items. Click on "Earth History" that opens a page with different periods. Click on each to look at how the Earth's continents have changed. An example of one of the maps is below - the Permian, when all the continents collided.
- The United States Geological Services websites listed below have great information about plate tectonics and maps of plate boundaries at the third site.
- Purdue University has a great flip book you can print, color-code continents, and watch them as they migrate to their current positions (the last website listed).

POWER WORDS

- **lava**: melted rock above ground
- **magma**: melted rock under ground

Websites:

- http://scotese.com
- https://pubs.usgs.gov/gip/dynamic/dynamic.html
- https://pubs.usgs.gov/imap/2800/
- https://web.ics.purdue.edu/~braile/edumod/flipbook/flipbook.pdf



Detangler - Clue Card
How Far to the Center of the Earth?

All of the measurements are approximate.
These are your clues to help solve the group's problem.
Read them to the group but do not show them to anyone.

Problem: Label the diagram of the Earth's interior, include the name and size of each area, and calculate the distance to the center.

Our planet has a layered structure.

The lower mantle is 1,320 miles thick.

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Problem: Label the diagram of the Earth's interior, include the name and size of each area, and calculate the distance to the center.

The inner core has a radius of 760 miles.

The outer core is largely liquid iron.

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Problem: Label the diagram of the Earth's interior, include the name and size of each area, and calculate the distance to the center.

The Earth's crust ranges in depth from 3-20 miles.

The upper mantle borders the crust and is 300 miles thick.

Detangler - Clue Card
How Far to the Center of the Earth?

All of the measurements are approximate.
These are your clues to help solve the group's problem.
Read them to the group but do not show them to anyone.

Problem: Label the diagram of the Earth's interior, include the name and size of each area, and calculate the distance to the center.

Scientific evidence support that the inner core is probably made of solid iron.

The Earth's crust is composed of rock.

Detangler - Clue Card
How Far to the Center of the Earth?

All of the measurements are approximate.
These are your clues to help solve the group's problem.
Read them to the group but do not show them to anyone.

Problem: Label the diagram of the Earth's interior, include the name and size of each area, and calculate the distance to the center.

The outer core, which is 1,400 miles thick, surrounds the inner core.

The crust is rigid, outermost part of the Earth.

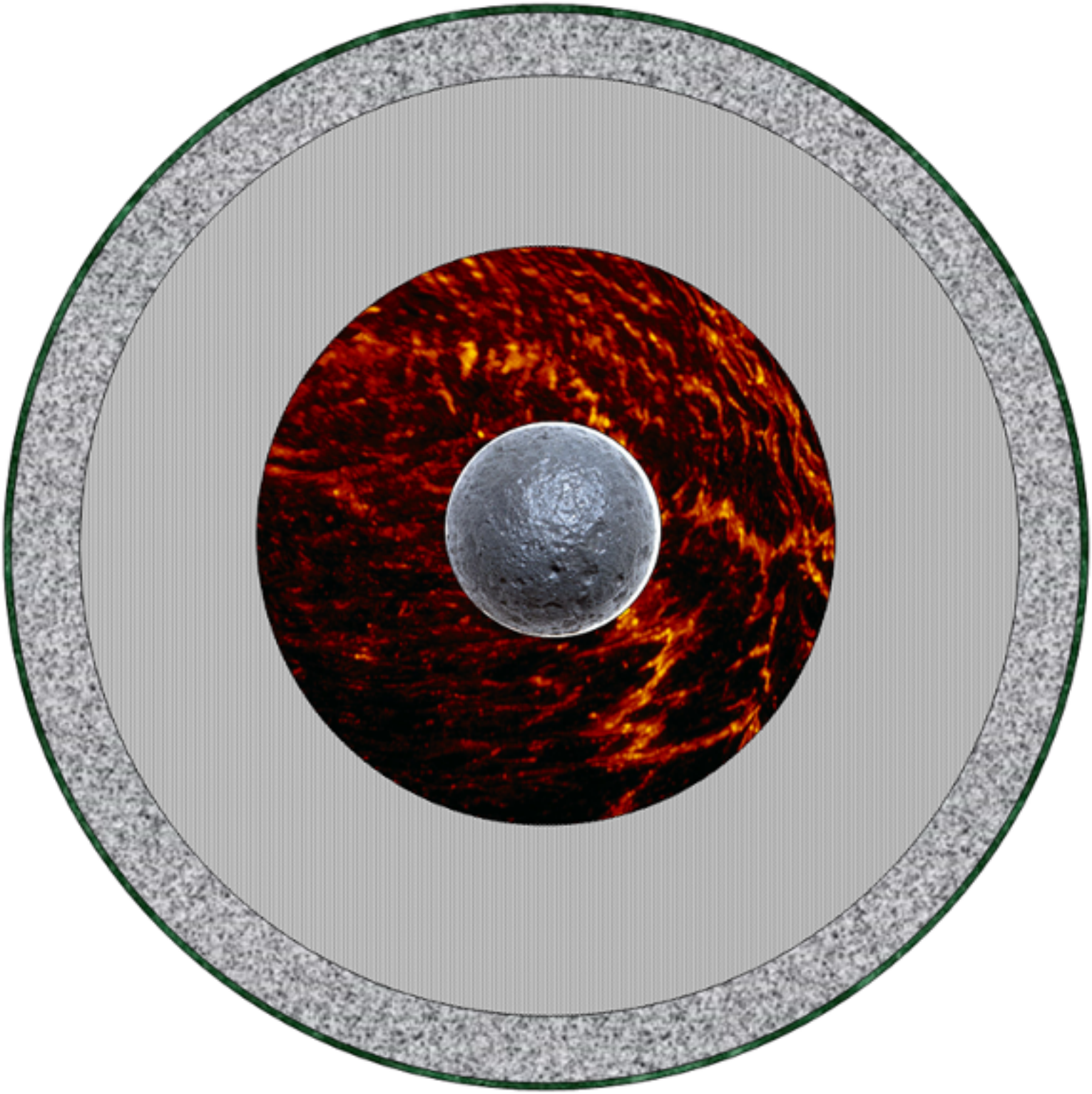
Detangler - Clue Card
How Far to the Center of the Earth?

All of the measurements are approximate.
These are your clues to help solve the group's problem.
Read them to the group but do not show them to anyone.

Problem: Label the diagram of the Earth's interior, include the name and size of each area, and calculate the distance to the center.

The estimated temperature at the Earth's core is 8,000°F.

The oldest known Earth rock dates back to 3.8 billion years.



Lower mantle	Crust	Upper mantle	Inner core	Outer core
760-mile radius	1,400 miles	3-20 miles	300 miles	1,320 miles
5-30 kilometers	2,110 kilometers	480 kilometers	2,240 kilometers	1,215 kilometers

ROCK CYCLE

Rocks are made from over 4,000 identified **minerals**, like feldspar, iron, and quartz. The rocks form one of three ways:

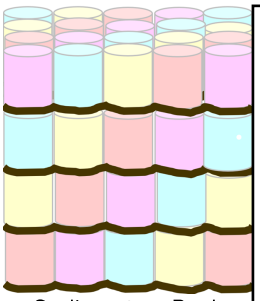
- Igneous: rock melted deep in the earth, then cooled. Igneous rock can **extrusive** as lava, or **intrusive** magma, and remain underground while cooling.
- Metamorphic: rock under pressure and / or heat.
- Sedimentary: **eroded** rock **particulates** cemented back together for form rock

Directions:

1. Do this activity on an approximate 12" x 12" piece of wax paper.
2. Use the frosting to make a thin layer on the wax paper about 2" square.
3. Place 25 marshmallows on the frosting, pressing down (each side is 5 marshmallows) using all 4 colors (pink, yellow, orange, and green).
4. Carefully frost the top of the marshmallows with the frosting in a thin layer.
5. Place 25 more marshmallows on top of your first layer. You now have two layers of marshmallows, using a total of 50 marshmallows.
6. Repeat steps 4 and 5 for a third and fourth row of marshmallows. You will used 100 marshmallows total. You do not need to frost the top.
7. This is like sedimentary rock. The marshmallows represent different **particulate** of rocks and minerals, and the frosting represents minerals dissolved in water that leach into the particulates and cement them together.
8. Fold the wax paper over the marshmallow. Pick up the marshmallows enveloped in the wax paper.
9. Place the marshmallows / frosting in the palms of your hands, and press tightly together. Gently rub your palms together to shift the columns of marshmallows while applying pressure between your hands. Hold for 5 minutes (heat and pressure).
10. Unfold the wax paper. The marshmallows, under heat and pressure, has changed to a flatter, semi-squeezed...mess! This is like metamorphic rock.
11. Scrape the marshmallow and frosting from the wax paper, and place in a small saucepan.
12. Ask for a parent's permission before the next step.
13. Slowly heat the marshmallow and frosting, stirring constantly, until they are melted.
14. This is like igneous rock. As rock moves deeper, it becomes hotter, until the materials finally melt. Igneous rock can be **extrusive** or **intrusive** and cool to form beautiful igneous rock.

POWER WORDS

- **erode**: gradually wear away by wind, water, or other natural agents
- **extrusive**: **magma** forced to the surface
- **intrusive**: forcing igneous rock through existing formation without reaching the surface
- **magma:** hot fluid or semi-fluid material below the Earth's surface
- **mineral**: a solid inorganic substance of natural occurrence
- **particulate**: in the form of minute separate particles



Sedimentary Rock Model

Marshmallows represent minerals & rocks; frosting represents minerals dissolved in water that will cement particulate together

MATERIALS:

- color mini-marshmallows
- wax paper
- frosting (any flavor)
- plastic knife
- small saucepan
- stove
- spoon
- pencil
- print page 14
- print page 15 (optimally on heavy paper like card stock)
- coin or other marker
- scissors
- tape

ROCK CYCLE GAME

This activity is modified from a game developed by NASA to explain how rocks are **recycled** on our planet.

You can plan this game either by yourself, or with other people. If you play by yourself, you only need to print pages 4-5 on single sheet paper. If you play with more people, each person needs to keep their own data. Use scratch paper, and copy the table on the bottom of page 14.

Directions:

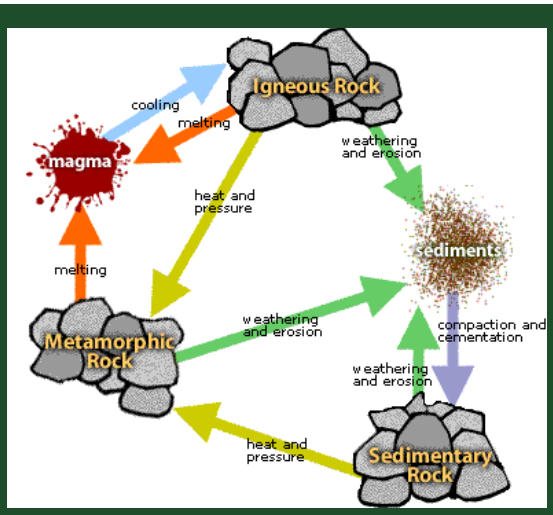
1. Print and cut out the cube **net** (page 15) on the outside solid lines, including the triangular tabs.
2. Place the **net** face down on a table, and fold up the paper on each line. Be as precise as you can on folding for a better end product.
3. Use the tabs to tape the cube together. It is tricky, but tape the triangular tabs to the inside of the cube. The last two are the most difficult.
4. Tape each edge of the cube.
5. Print the game board and data table (page 14).
6. Place your marker on Igneous Rock on the game board. Note that this is already recorded for you.
7. The cube you made is light. To "roll" your cube, throw it into the air to obtain better randomness of the roll. Record the roll **e.g.** Ocean Waves (Weathering and Erosion) on your data sheet.
8. Look at the game board and follow what happened to the rock towards the next type of rock. In our example above, Ocean Waves leads us to **sediments**, and the new rock formed through compaction and **cementation** is sedimentary rock, which you record in the third column, and the first column next row down.
9. Toss the cube in the air. Record the new conditions, determine what happens with the rock, and move to the new rock type.
10. Sedimentary rock can become igneous rock (melted), metamorphic rock (under different conditions of temperature and pressure), or another sedimentary rock (weathered and eroded).
11. Metamorphic rock can become igneous rock (melted), another metamorphic rock (under different conditions of temperature and pressure), or sedimentary rock (weathered and eroded)
12. Igneous rock can become another igneous rock (melted), another metamorphic rock (under different conditions of temperature and pressure), or sedimentary rock (weathered and eroded). When a rock melts, it loses its history to become a new rock.
13. Describe the rock cycle.

POWER WORDS

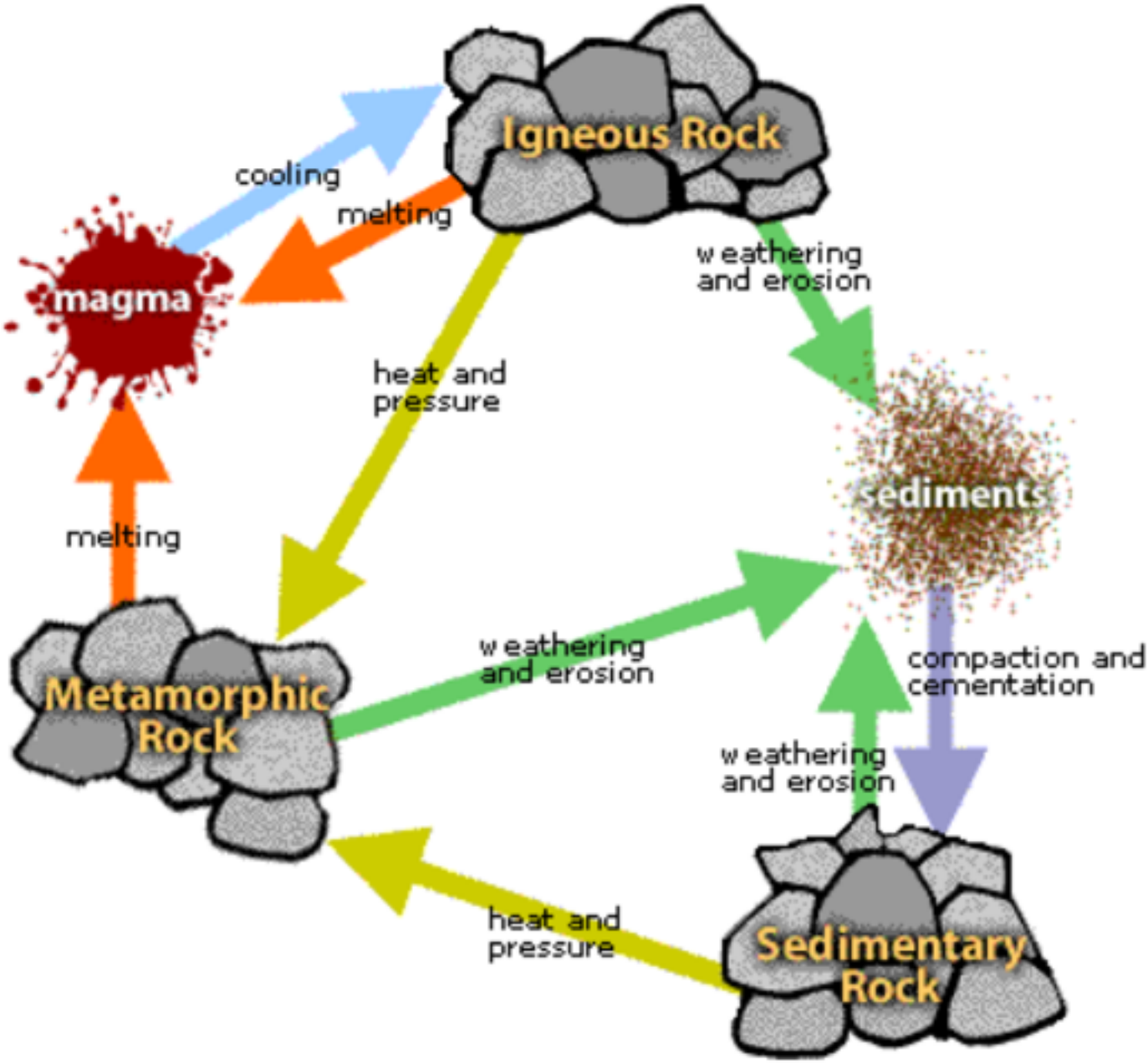
- **cementation**: the binding together of particles and sediment
- **compaction**: exertion of force on something that becomes more dense
- **net**: in geometry, a pattern you can cut and fold to make a model of a solid shape
- **recycle**: return material (rocks and minerals) to a previous stage in a cyclic process
- **sediment**: particulate matter carried by water or wind and deposited on the surface of land or bottom of a body of water

The only reason for time is so that everything doesn't happen at once.

Albert Einstein



Rock Cycle Game



Current Rock Type	Roll Cube: Effect on Rock	New Rock Type
Start on Igneous Rock		

Fold and tape

Hurricane (Weathering)

Fold and tape

High Heat (Melting)

Buried Underground (Heat and Pressure)

Ocean Waves (Erosion)

Fold and tape

Winter (Cooling)

Fold and tape

Fold and tape

Sunny Day (No Change)

Fold and tape

How old is the Earth? The oldest rock on Earth has been measured to 3.8 billion years old. A zircon crystal (a mineral) from Australia was dated to be 4.375 billion years old, and that is the oldest known piece of the Earth. The Earth, however, is older than that.

The rock cycle in the igneous stage melts minerals and rocks. These materials reform into igneous rock. All the original rock and mineral information is lost in this process, and only information from the point of **solidification** does the new rock story begin.

It is hard to find really old rock, because either it is buried where we can't find it, or it has already been recycled. This rock is still not as old as the Earth.

How can we determine the age of the Earth? Scientists make some assumptions:

- The Earth formed with the rest of the solar system formed
- Because of the rock cycle, the Earth no longer has any of the original rock that formed at the beginning of the solar system
- Meteorites formed with the rest of the solar system, but they are too small to have a rock cycle
- Meteorites that land on Earth can be dated and used as **proxy** for the age of the Earth

Scientists have dated meteorites (found on Earth) which formed at the same time as the rest of the solar system to 4.571 billion years old (rounded to 4.6 billion years).

Geologists divide the Earth into a series of time intervals. They are not equal in length, like hours in a day. Instead, they are divided by major geologic or paleontological events, **e.g.** mass extinctions. The divisions include:

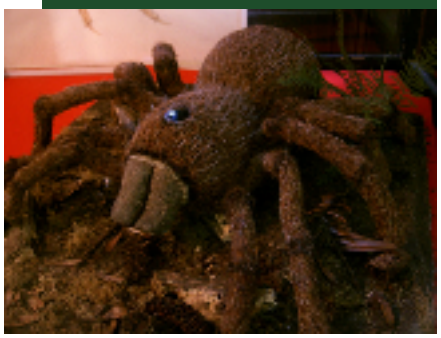
- There are four eons. These include the last 550 million years, called the Phanerozoic.
- The Phanerozoic is divided into three eras, Paleozoic, Mesozoic, and Cenozoic.
- Each era is divided in a different number of periods, **e.g.** Mesozoic has three periods: Triassic, Jurassic, and Cretaceous.
- Finally each era is divided into Epochs; this is most useful for the recent times.

A timeline is a **graphic** representation of the passage of time as a line.

Keep your timeline chart. You will be adding more information each month.

POWER WORDS

- **deep time**: the multi-million year time frame within which the earth has existed, and which is supported by the observation of natural, mostly geological, phenomena
- **graphic**: giving a vivid picture with explicit detail
- **solidification**: phase change from liquid to solid; freezing



Megarachne servinei fossil and model misidentified as an enormous spider 300 million years (~0.65 meter long). It is a sea scorpion.

MATERIALS:

- 20 feet (6 meters) butcher paper at least 24 inches (30.5 cm) wide (any color; you can find this in the paint section at a hardware store)
- sharpies in several colors
- meter stick
- masking tape
- ruler
- scissors
- adding machine paper at least 76 feet (912 inches)
- Computer with internet to download and/or print: https://www.geosociety.org/documents/gsa/timescale/timescl.pdf

Converting big numbers into physical objects (like 1 million and 1 billion cents) can make more sense of big numbers.

- If you travel 1 million miles around the Earth at the Equator, you can circle the Earth 40 times.
- If you travel 1 billion miles around the Earth at the Equator, you can circle the Earth 40,159 times.

Each 1 cm equals 2 million years (1 cm = 2,000,000 years).

Paleontologists use **metric** measurements, and therefore the timeline will **convert** time into **metric** length. FYI:

- 1 inch = 25.4 mm
- 1 inch = 2.54 cm
- 1 foot = 30.48 cm
- 1 yard = 91.44 cm
- 1 cm = 0.39 inches
- 1 yard = 1.1 meters

Keep the timeline for the entire year.
ST[EMpower] activities will continue adding information.

Directions:

- The history of Earth is divided into 4 major time periods:
  - Phanerozoic - multi-cellular life; 550 **MYA** to present
  - Proterozoic - oxygen-rich atmosphere to multi-cellular, soft-body organisms; 2.5 billion to 550 **MYA**
  - Archean - end of the heavy bombardment to oxygen in atmosphere; 4.0 to 2.5 **BYA**
  - Hadean - formation of the Earth; 4.6 to 4.0 **BYA**
- This timeline will include only the Phanerozoic, the past 550 million years. The Phanerozoic is divided into three periods: Paleozoic, Mesozoic, and Cenozoic.
- Roll out and measure 5.5 meters of butcher paper.
- Page 18 has a rough diagram of the geologic time scale you are making. Note that the first column divides the Eon Phanerozoic into the three Eras: Cenozoic, Mesozoic, and Paleozoic. The second column is for the name of the Periods in each Era, and the million year time span. The third column is left blank for now.
- Color code each era. For example, you can make the Paleozoic red, Mesozoic blue, and Cenozoic green.
- Draw the column lines the full length of your chart.
  - Measure the first column the length of the chart. The first column is 5-6 cm wide (about 2 inches), the width of your meter stick. Draw a line the full length of the chart, using the meter stick as a guide.
  - Measure the second column the length of the chart. The second column is 12 cm wide (about 5 inches). Draw a line the full length of the chart, using the meter stick as a guide.
  - The third column is the remaining width of the chart.

POWER WORDS

- **BYA**: billion years ago
- **column**: a vertical line of entries in a table
- **convert**: cause to change in form, character, or function
- **metric**: of or based on the meter as a unit of length; relating to the metric system
- **MYA**: million years ago
- **Phanerozoic**: eon covering time since the beginning of the Cambrian period to present
- **row**: horizontal line of entries in a table
- **table**: a set of facts arranged in rows and columns

Example of when *Triceratops* was alive:
Eon Phanerozoic
Era Mesozoic
Period Cretaceous

Triceratops horridus
American Museum of Natural History, New York, NY

- **Start from the bottom.** The table below is color-coded. The green in the third column are the measurement for the depth of each row. Black are labels you need for your chart.
- Measure from the bottom 27.5 cm on one side of the chart and mark with a dot. Measure from the bottom 27.5 cm on the other side of the chart and mark a dot. Align your meter stick at those two dots, and draw a line across the second and third column (not the first).
- Continue working your way up the chart, measure each side of the chart with that row's depth, align the dots, and draw the line across.
- Label your timeline with the information in black.
- Download (and optionally copy) the GSA (Geological Society of America) Geologic Time Scale.

Carnivorous dinosaur, Museo de La Plata, La Plata, Argentina.

	MYA = Million Years Ago 1 cm = 2 million years	**Phanerozoic Eon**
Cenozoic	**Quaternary** Today - 2.5 MYA	Measure 1.25 cm deep for this row
	Tertiary Upper (Neogene) 2.5 - 23 MYA	Measure 10.25 cm deep for this row
	Tertiary Lower (Paleogene) 23 - 66 MYA	Measure 21.5 cm deep for this row
Mesozoic	**Cretaceous** 66-145 MYA	Measure 39.5 cm deep for this row
	Jurassic 145 - 201 MYA	Measure 28 cm deep for this row
	Triassic 201 - 252 MYA	Measure 25.5 cm deep for this row
Paleozoic	**Permian** 252 - 299 MYA	Measure 23.5 cm deep for this row
	Carboniferous Upper (Pennsylvanian) 299 - 323 MYA	Measure 12 cm deep for this row
	Carboniferous Lower (Mississippian) 323 - 359 MYA	Measure 18 cm deep for this row
	Devonian 359 - 419 MYA	Measure 30 cm deep for this row
	Silurian 419 - 443 MYA	Measure 12 cm deep for this row
	Ordovician 443 - 485 MYA	Measure 21 cm deep for this row
	Cambrian 485 - 540 MYA	Measure 27.5 cm deep for this row

START MEASURING HERE and work your way up.

- The GSA Geologic Time Scale is to scale within each Era, but not among Eras or Eons (Cenozoic, Mesozoic, Paleozoic, and "Precambrian" are not scaled to each other.) Your timeline is scaled to everything in the Phanerozoic.
- Your geologic timeline is almost 3 meters (9 feet) long. The Cambrian denotes when life developed hard parts: shells, and later teeth, exoskeletons, and bones. Hard-body parts have a greater chance to preserve than soft-body parts do. There are multi-cellular organisms in the fossil record before the Cambrian, but they are soft-bodied organisms, so extremely rare.
- Switch to the adding machine paper. Tape the meter stick on a table top. The end of the adding machine tape represents the formation of our solar system. The green box on the bottom right has a rough diagram of the remaining three Eons and their measurements.
- Label the bottom of the paper "Hadean." Measure from the bottom 300 cm (3 m) of the adding machine paper and mark with a dot. With your ruler, draw a line across the paper. Label under the line "Hadean" to denote the beginning and end of the Hadean Eon.
- Above the line, write "Archean." Measure from the bottom 750 cm (7.5 m) of the adding machine paper and mark with a dot. With your ruler, draw a line across the paper. Label under the line "Archean" to denote the beginning and end of the Archean Eon.
- Above the line, write "Proterozoic." Measure from the bottom 980 cm (9.8 m) of the adding machine paper and mark with a dot. With your ruler, draw a line across the paper. Label under the line "Proterozoic" to denote the beginning and end of the Proterozoic Eon. Cut your Precambrian timeline above the Proterozoic line.
- You will add more information to this timeline in the following issues, so keep this paper. You can use a toilet paper tube and roll the timeline on it to store.
- On a sunny day, head outside with your two timelines.
- Lay out the Proterozoic Eon timeline on the ground. You may need something (like small rocks) to weigh it down if there is a wind. Place the adding machine paper at the bottom of the Phanerozoic timeline and add a weight). Unroll the adding machine paper.
- What observations can you make about your timeline?
- What can you say about each Eon?
- Store everything for next month.

POWER WORDS

- **Archean**: the eon that constitutes the middle part of the Precambrian, and first fossil evidence of bacterial life
- **Hadean**: the eon that constitutes the earliest part of the Precambrian, when the Earth was forming
- **Precambrian**: a term for the earliest three eons of the earth's history, preceding the Cambrian period in the Paleozoic Era, including the Hadean, Archean, and Proterozoic
- **Proterozoic**: the eon that constitutes the later part of the Precambrian, in which soft-bodied organisms and bacteria become abundant

Fossil monkey, American Museum of Natural History, New York, NY

Proterozoic 2.5 BYA - 540 MYA Measure 980 cm (9.8 meters) deep	
Archean 4 - 2.5 BYA Measure 750 cm (7.5 meters) deep	Adding Machine Paper Timeline of the first three Eons is 89% of the total history of Earth!
Hadean 4.6 - 4 BYA Measure 300 cm (3 meters) deep	

pneumonoultramicroscopicsilicovolcanoconiosis

This is the longest word in the English language. At the end of the activity, you will define the word (although you may have to practice pronouncing it!).

Scientific names and words can seem like a foreign language, yet most of the fragments making up these **incomprehensible** words are **derived** from Latin or Greek. If you learn to identify and define the small parts, you can understand these words. That is how you will identify and define the word above to learn the meaning of the entire word.

Directions:

- Print the Word Pieces on both sides of the paper. On one side will be the "**BASIC**" word piece, and on the other side will be the "meaning" of that word piece.
  - Page 22 and 23 on one piece of paper
  - Page 24 and 25 on a second piece of paper
  - Page 26 and 27 on a third piece of paper
  - Page 28 and 29 on a fourth piece of paper
- Hold the printed page to the light to make sure that the boxes align on the front and back before cutting them apart to make your 64 word cards.
- On your Word Pieces Data Sheet (page 21), complete **Section 1** on common words that are made of word pieces.
- What other common words can you break into word pieces?
- **Section 2**: Lay the cards in front of you with the lower-case words (meanings) facing up.
- Use your Word Pieces data sheet to record your answers.
- Find the word pieces listed, turn over the cards, and write out the basic word pieces in order to figure out who the two animals are.
- Look at the image. Using your word piece cards, what would you name this creature?
- On the back of the data sheet, draw a mythical beast. Use the meaning word cards to describe it. Turn the word cards over, and name your beast!
- **Section 3**: Turn all your cards over so that the capitalized **BASIC** word pieces are face up and the word meanings are face down.
- What do pachycephalosaurus, ichthysaurus, and octopus mean? Can you guess? Find basic word pieces, turn them over to find out what each means.
- Challenge: can you figure out the meaning of the 45-letter word at the top of this page?

POWER WORDS

- **derive**: a word that has its root origin from another language
- **incomprehensible**: not able to be understood

Dr. Laurie Schlitter developed this activity as a lesson for teachers (complete lesson with the aligned standards for this lesson). She is editing it for the ST[EMpower] newsletter.

Phascolonus, early marsupial; American Museum of Natural History , New York, NY

MATERIALS:

- print Word Pieces Data Sheet page 21
- print Word Cards pages 22 - 29 double sided
- pencil
- scissors
- colored pencils
- paper

WORD PIECES - Data Sheet

Section 1: Intro Word Pieces

Break words into pieces, define each piece. What does it mean?

Example:

bicycle

bi / cycle

What does bi mean?

two

What does cycle mean?

wheel

You try these two variations:

tricycle

unicycle

Here are some new words:

microscope

telescope

Can you think of six other words that can you break into word pieces?

1.

2.

3.

4.

5.

6.

Section 2: Word Cards Meaning

Write the basic word piece that is on the back of the following words:

three:

horn:

face:

What animal is this?

eight:

feet:

What animal is this?

Make up a name for this animal:

Word Piece Meaning

Draw a make-believe animal on the back of this paper, and name it with word pieces.

Section 3: Word Cards Words

Write the word meaning on the back of the following words:

rhino:

ceros:

How about this one:

Ichthyosaurus

ichthy:

saur:

One more:

Pachycephalosaurus

pachy

cephalo

saur

What does pneumonoultramicroscopicsilicovolcanoconiosis mean? (Chop it into word pieces first.)

A, AN	**CERATO, KERATO**
ARACHNI	**CHEL**
ARTHRO	**DACTYL**
BI, DI, DIPLO	**DENT, DONT**
BIO	**DERM**
BRADY	**ECHINO**
CAUD	**EN, ENDO**
CEPHALO	**EXO**

horn	not, without
claws	spider
finger or toe	joint
tooth, teeth	two, double
skin	life
spiny	slow
in, into, within, inner	tail
out, outside	head

GASTRO	**MEGA, MACRO**
GEO	**MICRO**
GNATHO	**MOLLI**
GON	**MYS**
GYMNO	**MYXO**
HEMI	**NEO**
ICHTHY	**OCTO**
ITIS	**OLOGY**

large, big	stomach
small	earth
soft	jaw
mouse	angle
slimy	naked
new	half
eight	fish
study of	inflammation

OPS	**PHIL**
ORTHO	**PHOB**
OSIS	**PHOTO**
OSTEO	**PLATY**
OTO	**PNEUMO**
PACHY	**POD, PUS, PED**
PALEO	**POLY**
PENTA	**POST**

love	face
fear of	straight
light	disease
flat	bone
lung	ear
foot	thick
many	ancient
after, behind	five

PRE	**SCOPE**
PSEUDO	**SUB**
PTERO	**SUPER**
REPT	**THERMO**
RHINO	**TRI**
RUG	**ULTRA**
SAUR	**VERMI**
SCLERO	**ZO, ZOA**

to see, watch, look	before
below, under	false
above, over	wing
heat	creeping
three	nose
beyond	wrinkled
worm	lizard
animal	hard

BASE	Definition	**BASE**	Definition
A, AN	not, without	**OPS**	face
ARACHNI	spider	**ORTHO**	straight
ARTHRO	joint	**OSIS**	disease
BI, DI, DIPLO	two, double	**OSTEO**	bone
BIO	life	**OTO**	ear
BRADY	slow	**PACHY**	thick
CAUD	tail	**PALEO**	ancient
CEPHALO	head	**PENTA**	five
CERATO, KERATO	horn	**PHIL**	love
CHEL	claws	**PHOB**	fear of
DACTYL	finger or toe	**PHOTO**	light
DENT, DONT	tooth, teeth	**PLATY**	flat
DERM	skin	**PNEUMO**	lung
ECHINO	spiny	**POD, PUS, PED**	foot
EN, ENDO	in, into, within, inner	**POLY**	many
EXO	out, outside	**POST**	after, behind
GASTRO	stomach	**PRE**	before
GEO	earth	**PSEUDO**	false
GNATHO	jaw	**PTERO**	wing
GON	angle	**REPT**	creeping
GYMNO	naked	**RHINO**	nose
HEMI	half	**RUG**	wrinkled
ICHTHY	fish	**SAUR**	lizard
ITIS	inflammation	**SCLERO**	hard
MEGA, MACRO	large, big	**SCOPE**	to see, watch, look
MICRO	small	**SUB**	below, under
MOLLI	soft	**SUPER**	above, over
MYS	mouse	**THERMO**	heat
MYXO	slimy	**TRI**	three
NEO	new	**ULTRA**	beyond
OCTO	eight	**VERMI**	worm
OLOGY	study of	**ZO, ZOA**	animal

CAREER JOURNAL - Throughout this process, keep a journal that includes all this information in one place. At the end of this series (2021 in May), you will have a lot of information (see the Career Series in the green box on the right). For now, keep everything in your journal, notebook or file. You will organize it at the end of this journey.

The first step in exploring careers, determine what your interests and talents are. Circle each response if it is something that you would really like to do, or you do regularly. There is no wrong answer unless you do not answer honestly! Be picky!

1. Rescue a cat stuck in a tree.
2. Visit the pet store every time you go to the mall.
3. Paint a mural on the cafeteria wall.
4. Run for a 4-H county council officer position.
5. Send e-mail to a "4-H pen pal" in a different state.
6. Survey your 4-H club members to find out what they do after school.
7. Try out for the school play.
8. Dissect a frog and identify the different organs.
9. Play baseball, soccer, basketball, football, or _____ (fill in your favorite sport).
10. Talk on the phone to just about anyone who will talk back.
11. Try foods from all over the world: Thailand, Poland, Japan, etc., and do the Passport to Foreign Cookery project.
12. Write poems about things that are happening in your life.
13. Create a really scary haunted house to take your friends through on Halloween.
14. Raise a 4-H lamb for breeding or market and enter in the county fair.
15. Bake a cake and decorate it for your best friend's birthday in the cake decorating project.
16. Sell enough advertisements for the school yearbook to win a trip to Walt Disney World.
17. Simulate an imaginary flight through space on your computer screen.
18. Build model airplanes, boats, doll houses, or anything from scratch or a kit. Model rocket or woodworking heritage arts.

Continued next page.

CAREER SERIES

What do you want to be when you grow up? The ST[EMpower]'s issues over the next two years will provide fun activities to help you start exploring your future!

- Interest Survey
- Analyze Interest
- Projects focused on your interests
- Your Lifestyle
- Job Satisfaction
- How to find careers that match your interests
- Interviewing
- Job Shadowing
- Education Required
- Organizing Information

Lesodon armatus, American Museum of Natural History, New York, NY

MATERIALS:

- print pages 31-33
- notebook, journal, or file
- color pencils
- glue stick or tape
- pencil or pen

Keep this quiz until next month for analyzing the results.

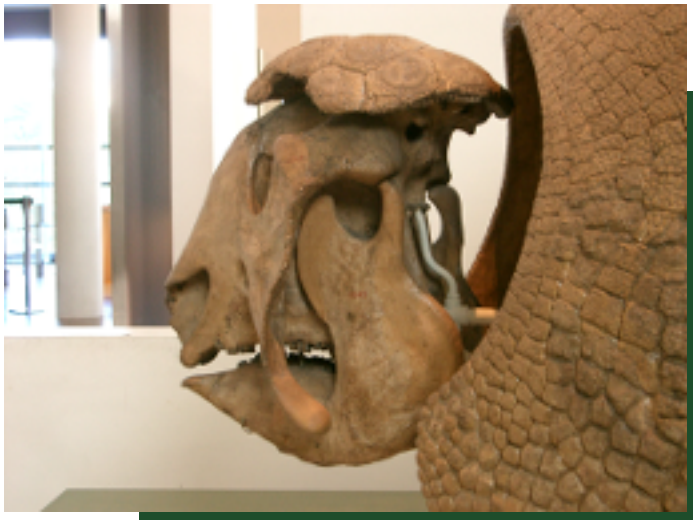
19. Teach your friends a new dance routine.
20. Watch the stars come out at night and see how many constellations you can find.
21. Watch baseball, soccer, basketball, football, or _____ (fill in your favorite sport) on TV.
22. Give a speech in front of your 4-H council.
23. Go to Washington D.C. on the Citizenship Washington Focus with your state 4-H teen leaders.
24. Read everything in sight, including the back of the cereal box.
25. Figure out "who dunnit" in a mystery story.
26. Take in stray or hurt animals.
27. Make a display board about your 4-H project.
28. Think up new ways to make lunch line move faster and explain it to the cafeteria staff.
29. Make your own movie in the 4-H film making project.
30. Invest your allowance in the stock market and keep track of how it does.
31. Go to the ballet or opera every time you get the chance.
32. Do experiments with a chemistry set.
33. Keep score at your sister's little league team game.
34. Use lots of funny voices when reading stories to children.
35. Ride on airplanes, trains, boats, anything that moves.
36. Interview the new exchange student for an article in the monthly 4-H County Newsletter.
37. Build your own tree house.
38. Help clean up a waste site in your neighborhood.
39. Visit an art museum and pick out your favorite painting.
40. Play Monopoly in an all-night championship challenge.
41. Make a chart on the computer to show how much soda students buy from the school vending machine each week.
42. Keep track of how much your team earns to buy new uniforms.
43. Plan an instrument in the school band or orchestra.
44. Take things apart and put them back together in the Small Engines project.
45. Write stories about sports for the school newspaper.
46. Listen to other people talk about their problems.
47. Imagine yourself in exotic places.
48. Hang around bookstores and libraries.
49. Play harmless practical jokes on April Fool's Day.
50. Join one of the 4-H clubs in your county.

Continued next page.

CAREER JOURNAL

- Your career journal needs to take on your personality. Make it part of you. Decorate it, include things that make you happy or feel good, and reflect who you are.
- Date your journal. You may need to use many journals, and dating them helps you keep them in **chronological** (of a record of events starting with the earliest and following the order in which they occurred) order.
- Number the pages.

Keep this until next month to analyze the results.



Glyptotherium texanum, American Museum of Natural History, New York, NY

51. Take photographs at the school talent show.
52. Make money by setting up your own business—paper route, lemonade stand, etc.
53. Create an imaginary city using a computer.
54. Do 3-D puzzles.
55. Keep track of the top 10 songs of the week.
56. Read about famous inventors and their inventions.
57. Make play-by-play announcements at the school football game.
58. Answer the phones during a telethon to raise money for orphans.
59. Be an exchange student in another country with the 4-H International Programs.
60. Write down all your secret thoughts and favorite sayings in a journal.
61. Jump out of an airplane (with a parachute, of course!).
62. Plant and grow a garden in your backyard (or windowsill) in the gardening project.
63. Use a video camera to make your own movies.
64. Get your friends together to help clean up your town after a storm.
65. Spend your summer at a computer camp learning lots of new computer programs.
66. Build bridges, skyscrapers, and other structures (like robots) out of LEGOs.
67. Plan a concert in the park for little kids.
68. Collect different rocks.
69. Help plan a sports tournament.
70. Be DJ for the school dance.
71. Learn how to fly a plane or sail a boat.
72. Write funny captions for pictures in the school yearbook.
73. Scuba dive to search for buried treasure.
74. Recognize and name several different breeds of cats, dogs, and other animals.
75. Sketch pictures of your friends.
76. Pick out neat stuff to sell at the school store.
77. Answer your classmates' questions about how to use the computer.
78. Draw a map showing how to get to your house from school.
79. Make up new words to your favorite songs.
80. Take a hike and name the different kinds of trees, birds, or flowers.
81. Referee intramural basketball games.
82. Join the school debate team.
83. Make a poster with postcards from all the places you went on your summer vacation.
84. Write down stories that your grandparents tell you about when they were young.

POWER QUOTES

Try not to become a person of success, but rather try to become a person of value.

Albert Einstein

"Person" substituted for "man."

To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science.

Albert Einstein

Once we accept our limits, we go beyond them.

Albert Einstein

Keep this until next month to analyze the results.

Ground sloths, glyptodonts, and Hank J. Edmunds kneeling (for scale), Museo de La Plata, La Plata, Argentina

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Doug Garcia, Colorado State University Creative Services Communication Coordinator/ Designer

CITATIONS

Information:
Model of the Earth - orange: http://www.perkinselearning.org/accessible-science/activities/plate-tectonics-edible-model

- Word Pieces:
  - References: Bioscientific Terminology: Words from Latin and Greek Stems. Donald M. Ayres. 1972. University of Arizona Press.
  - Dictionary of Word Roots and Combining Forms. Donald J. Borror. 1960. N-P Publications, Palo Alto, CA. Out of Print.
  - Composition of Scientific Words. Roland Wilbur Brown. 2000. Smithsonian Books.
- Quotes: https://www.brainyquote.com/authors/albert_einstein
- Careers: Reeves, Diane Lindsey and Clasen, Lindsey (2007) Career Ideas for kids who like Science 2nd Edition. Checkmark Books, New York NY; Pp7-26.

Images:

- Unless otherwise indicated, all images are taken by Barbara J. Shaw, Ph.D. from the American Museum of Natural History, New York, NY or Museo de La Plata, La Plata, Argentina.
- Earth's New World plate boundaries: https://svs.gsfc.nasa.gov/1288
- Rock Cycle: https://www.nasa.gov/sites/default/files/rockingtherockcycle.pdf
- Stacks of pennies Cannot located original source) Now located Imagination Station: https://www.imaginationstationtoledo.org/educator/activities/what-does-14-trillion-of-something-look-like
- Griffin: https://vignette.wikia.nocookie.net/harrypotter/images/f/f8/Griffin.png/revision/latest?cb=20170413064633
- Ichthyosaurus: https://www.amnh.org/exhibitions/permanent/vertebrate-origins/stenopterygius-quadriscissus
- Pachycephalosaurus: https://www.dkfindout.com/us/dinosaurs-and-prehistoric-life/dinosaurs/pachycephalosaurus/

Answers from page 2:

- How would you write 76,250,000 as a scientific notation? 7.625×10^7
- What is this number: 62.5×10^{21} 62,500,000,000,000,000,000,000 (sixty-two sextillion, five hundred quintillion)
- What is this number: 7×10^3 7,000 (seven thousand)

Answer from pages 3-4

- $43,035,996,273,705 (45 trillion, 35 billion, 996 million 273 thousand, 750 dollars.

Answers from pages 5-6:

- One million seconds are 1 week, 4 days, 13 hours, 46 minutes, and 40 seconds
- One billion seconds are 31 years, 259 days, 1 hour, 46 minutes, and 40 seconds.

Answers from page 9-10:

- Answer: 3800 miles to the center of the Earth

Answer to from page 20:

- lung disease caused by inhaling very fine ash and sand dust from volcano ash..
- pneumono: lung
- ultra: beyond
- micro: tiny
- scopic: to see, watch, look
- silico: the main mineral in magma and volcanic ash is silica
- volcano: volcano (shocker)
- coni: with
- osis: abmormal or diseased